Proceedings of the American Academy of Arts and Sciences.

Vol. XLIV. No. 19. — May, 1909.

CONTRIBUTIONS FROM THE ROGERS LABORATORY OF PHYSICS, MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

LII. — *A PHOTOGRAPHIC STUDY OF MAYER'S FLOATING MAGNETS.*

By Louis Derr.

With a Plate.

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LII. — A PHOTOGRAPHIC STUDY OF MAYER'S FLOATING MAGNETS.

By Louis Derr.

Presented February 10, 1909. Received January 13, 1909.

Though Professor A. M. Mayer's beautiful experiment of floating magnetized needles over a magnetic pole has been variously modified in details, it has for many years been regarded chiefly as an interesting study of a rather special set of forces; but the recent investigations into the structure and possible electrical nature of the atom have lent a new interest to the equilibrium figures formed by the floating magnetic poles, and have suggested that they may illustrate the arrangement of sub-atomic corpuscles, at least in the limited degree possible in two dimensions. Mayer's original paper[1] gives drawings of 8 arrangements of 3 to 7 needles, and a later one[2] gives all the configurations of 2 to 8 needles. A fuller discussion[3] gives a list of all the configurations up to 51, with drawings up to 20 needles. Professor R. W. Wood[4] showed that bicycle balls could be used, and gives 20 symmetrical figures. I have therefore thought it might be of interest to assemble pictures of an entire series, in order to show the progression from one form to another more clearly than can be done by tables; and the accompanying Plate is a reproduction from photographs of the more stable forms assumed by the magnets when their number is varied from 1 to 52.

The magnets were clean quarter-inch steel balls, floated on freshly-filtered mercury as described by Wood, but initially magnetized by placing them one by one between the jaws of a powerful electromagnet. Equilibrium figures may be obtained with unmagnetized balls, both hard and soft; but the magnetized balls are more easily managed, as

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[1] American Journal of Science, **95**, 276.
[2] Ibid., p. 477.
[3] Ibid., **96**, 247.
[4] Phil. Mag., Ser. 5, **46**, 162.

the unmagnetized ones are apt to draw into contact and spoil the figure unless kept several diameters apart. The balls are much more convenient than needles; and as they give very nearly the same figures, the law of force cannot be very different in the two cases.

Professor J. J. Thomson [5] has discussed the stability conditions of a ring of negatively electrified corpuscles within a sphere of positive electricity, and has given a method of calculating the minimum number of such corpuscles required to hold an outer ring of a given number in stable equilibrium. It is interesting to compare the figures actually obtained with the results of the calculation. Complete agreement can hardly be expected, partly because the calculated numbers are minimum values and may represent in some cases forms of such slight stability that they might be difficult to reproduce, but chiefly because the law of force in the concrete case is quite different from the simple law of electric attraction. With the floating balls only the horizontal component of the central attraction is available in producing motion toward the centre of the figure; and as this is an increasing fraction of the entire force as the distance from the centre increases, the pull on a large outer ring is virtually increased and a larger number of balls will be required to hold it in equilibrium. This is exactly what takes place, as may be seen from the accompanying table, where for a considerable number of balls the number inside the outer ring is almost always larger than the calculated minimum.

The configurations shown are those obtainable without much difficulty, no special effort having been made to secure forms of very slight stability. In fact, with perfectly clean balls and mercury it is not easy to obtain many "isomers" unless the apparatus is very free from vibration, a figure which is quite stable enough to be photographed sometimes working itself over into quite another form after five or ten minutes. The effects of surface tension modify the results greatly, as shown by A. W. Porter,[6] who was able to obtain a ring of fifteen magnets without a central nucleus, in a dish of water filled to overflowing. Lack of perfect equality in the balls will distort figures otherwise symmetrical, and if the mercury surface is even slightly dirty the inner balls arrange themselves with nearly uniform spacing, without much reference to the number in the outer ring. The white lines in the figures have been drawn upon the negatives to mark the contours, and are not a part of the experiment. The figures clearly show the periodic nature of the structure, as has been noted from the first; the larger figures are obtained from the smaller by the simple addition of more

[5] Phil. Mag., Ser. 6, **7**, 237.

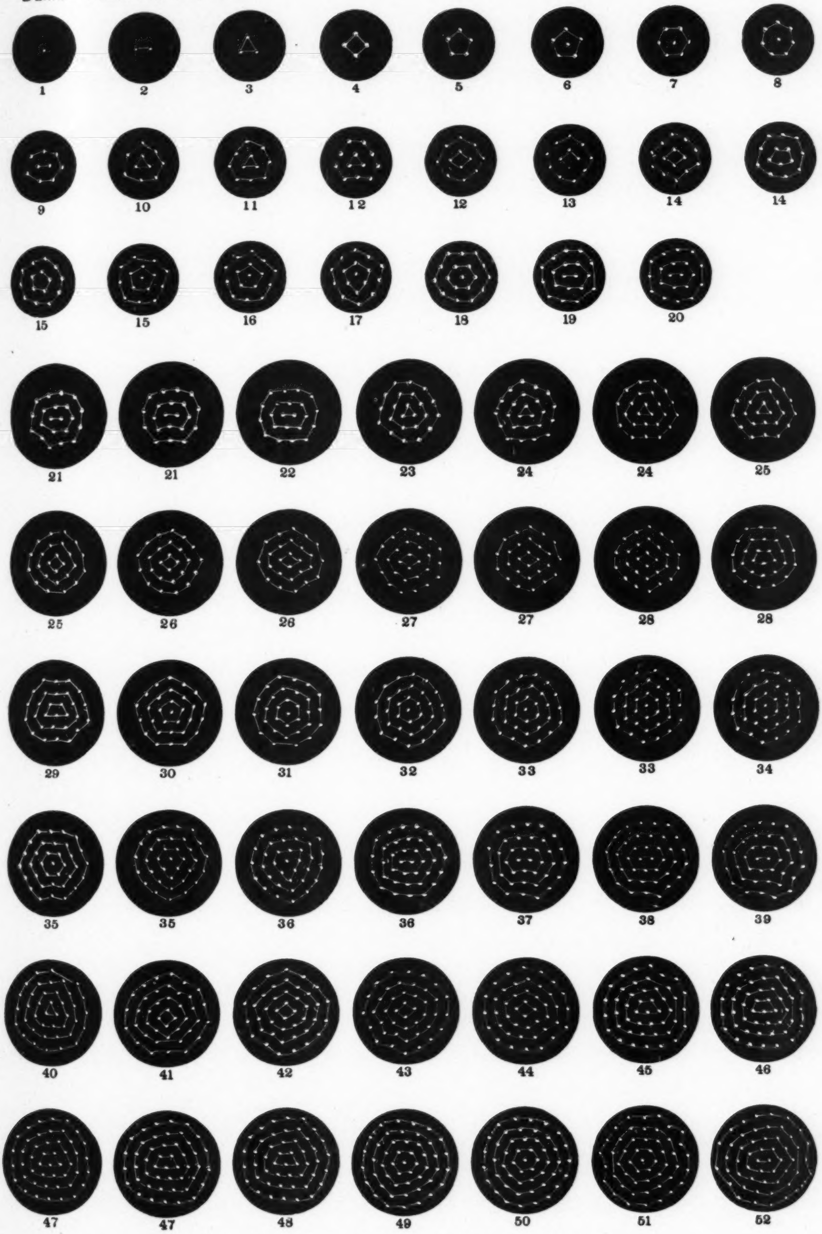
[6] Nature, **64**, 563.

CONFIGURATIONS AS CALCULATED AND OBSERVED.

Number of Magnets.	Calculated Rings.	Calculated Rings photographed.	Other Forms photographed.
1 to 5	1 to 5	1 to 5	...
6	1- 5	1- 5	...
7	1- 6	1- 6	...
8	1- 7	1- 7	...
9	1- 8	...	2- 7
10	2- 8	...	3- 7
11	3- 8	3- 8	...
12	3- 9	...	4- 8
13	3-10	...	4- 9
14	4-10	4-10	5- 9
15	5-10	5-10	1- 5- 9
16	5-11	...	1- 5-10
17	1- 5-11	...	1- 6-10
18	1- 6-11	1- 6-11	...
19	1- 6-12	...	2- 7-10
20	1- 7-12	...	2- 7-11
21	1- 8-12	...	2- 7-12 and 2- 8-11
22	1- 8-13	...	2- 8-12
23	2- 8-13	...	3- 8-12
24	3- 8-13	3- 8-13	3- 9-12
25	3- 9-13	3- 9-13	4- 9-12
26	3- 9-14	...	4- 9-13 and 4-10-12
27	3-10-14	...	4- 9-14 and 4-10-13
28	4-10-14	4-10-14	...
29	5-10-14	5-10-14	...
30	5-10-15	...	1- 5-10-14
31	5-11-15	...	1- 6-11-13
32	1- 5-11-15	...	1- 6-11-14
33	1- 6-11-15	1- 6-11-15	1- 6-12-14
34	1- 6-12-15	1- 6-12-15	...
35	1- 6-12-16	1- 6-12-16	1- 7-12-15
36	1- 7-12-16	...	1- 8-12-15 and 2- 7-12-15
37	1- 8-12-16	...	2- 8-12-15
38	1- 8-13-16	...	2- 8-12-16
39	2- 8-13-16	2- 8-13-16	...
40	3- 8-13-16	...	3- 9-13-15
41	3- 8-13-17	...	4- 9-13-15
42	3- 9-13-17	...	4- 9-14-15
43	3- 9-14-17	...	4- 9-14-16
44	3-10-14-17	...	4-10-14-16
45	4-10-14-17	...	5-10-13-17
46	5-10-14-17	5-10-14-17	...
47	5-10-15-17	5-10-15-17	5-10-14-18
48	5-10-15-18	5-10-15-18	...
49	5-11-15-18	...	1- 6-11-14-17
50	1- 5-11-15-18	...	1- 6-11-14-18
51	1- 6-11-15-18	1- 6-11-15-18	...
52	1- 6-12-15-18	...	2- 7-12-14-17

and larger rings. With fifty-two balls the central nucleus changes again from one to two, and the series continues much as before; but the figures are much crowded, and unless the balls are perfectly uniform it is often difficult to decide just which ones go to form particular rings.

The preceding table presents the results as calculated by the Thomson method and as photographed. It is curious that so many of the calculated minimum numbers should be obtainable with ease; with care in manipulation of the balls I have obtained a number of others, but not of sufficient stability to be photographed on the vibrating floor where the experiments were carried out.


1 2 3 4 5 6 7 8
9 10 11 12 12 13 14 14
15 15 16 17 18 19 20
21 21 22 23 24 24 25
25 26 26 27 27 28 28
29 30 31 32 33 33 34
35 35 36 36 37 38 39
40 41 42 43 44 45 46
47 47 48 49 50 51 52